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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: ANDRE

Docket: 9320.100US01

Title: RADIOFREQUENCY TRANSMITTER WITH A HIGH DEGREE OF INTEGRATION AND POSSIBLY WITH SELF-CALIBRATING IMAGE DELETION

CERTIFICATE UNDER 37 CFR 1.10
'Express Mail' mailing label number. EL435546999US
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By: [signature]
Name: Wade Klingseisen

BOX PATENT APPLICATION
Assistant Commissioner for Patents
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- ☒ Utility Patent Application: Spec. 25 pgs; 13 claims; Abstract 1 pg.
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- ☒ 1 sheet of formal drawings
- ☒ An unsigned Combined Declaration and Power of Attorney
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Number of Claims Filed		In Excess of:		Number Extra		Rate		Fee
Basic Filing Fee								$690.00
Total Claims								
13	–	20	=	0	x	18.00	=	$0.00
Independent Claims								
1	–	3	=	0	x	78.00	=	$0.00
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Initials: JJG:tvm

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S/N Unknown PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant:	ANDRE	Examiner:	Unknown
Serial No.:	Unknown	Group Art Unit:	Unknown
Filed:	March 6, 2000	Docket No.:	9320.100US01
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By: ____________
Name: Wade Klingseisen

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D. C. 20231

Dear Sir:

In connection with the above–identified application filed herewith, please enter the following preliminary amendment:

IN THE CLAIMS

In claim 3, lines 1 & 2, delete "any one of Claims 1 and 2" and insert—claim 1—

In claim 4, lines 1 & 2, delete "any one of Claims 1 to 3" and insert—claim 1—

In claim 5, lines 1 & 2, delete "Claims 3 and 4" and insert—claim 3—

In claim 6, lines 1 & 2, delete "any one of Claims 1 to 5" and insert—claim 1—

In claim 10, lines 1 & 2, delete "any one of Claims 8 and 9" and insert—claim 8–

In claim 11, lines 1 & 2, delete "any one of Claims 7 to 10" and insert—claim 7—

In claim 12, lines 1 & 2, delete "any one of Claims 6 to 11" and insert—claim 6—

In claim 13, line 2, delete "and any one of Claims 6 to 12"

REMARKS

The above preliminary amendment is made to remove multiple dependencies from claims 3, 4, 5, 6, 10, 11, 12, 13.

Applicants respectfully request that the preliminary amendment described herein be entered into the record prior to calculation of the filing fee and prior to examination and consideration of the above–identified application.

If a telephone conference would be helpful in resolving any issues concerning this communication, please contact Applicants' primary attorney–of record, John J. Gresesn (Reg. No. 33,112), at (612) 371.5265.

Respectfully submitted,

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Dated: March 6, 2000

By ____________________
John J. Gresens
Reg. No. 33,112

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RADIOFREQUENCY TRANSMITTER WITH A HIGH DEGREE OF INTEGRATION AND POSSIBLY WITH SELF-CALIBRATING IMAGE DELETION

The field of the invention is that of transmitting signals by a frequency channel.

It will be recalled that transmission of a signal by a frequency channel more and more often calls upon digital modulation, the main advantage of which is that it permits the use of signal processing algorithms. The purpose of these algorithms is to increase the strength of the signal to be transmitted relative to the propagation channel.

More precisely, the invention relates to a radiofrequency transmitter of the type supplied by two signals (or components) in baseband and in quadrature i(t) and q(t), which are images of two binary streams representing a piece of information to be transmitted. In effect, whatever the type of digital modulation, the signal to be transmitted m(t) can be written :

$m(t)=i(t).\cos(\omega t)-q(t).\sin(\omega t)$, where ω ($=2\pi f$) is the transmission frequency of the signal (also called the carrier frequency).

In the state of the technology, different types of radiofrequency transmitter are known, each based on a distinct architecture. The most widely known are the radiofrequency transmitter with frequency transposition, the radiofrequency transmitter with direct conversion and the radiofrequency transmitter with a phase locked loop. Their respective disadvantages will now be discussed.

The radiofrequency transmitter with frequency transposition which permits transposition to an intermediate frequency FI, requires the use of selective pass band filters, so as to reject the image frequency of the wanted signal to be transmitted. This first type of radiofrequency transmitter provides good performance, thanks to frequency transposition into the digital domain. However, the requirement to use high performance filters restricts its degree of integration onto silicon.

The radiofrequency transmitter with direct conversion has the most simple architecture and offers a high degree of integration. Its weak point is its high sensitivity to the performance of the elements that make it up. In particular, it is recommended that any leakage from the conversion oscillator via the mixer be avoided or that provision is made for perfect quadrature of the sine and cosine signals. These imperatives are often difficult to keep to.

The radiofrequency transmitter with a phase locked loop offers numerous advantages, such as the ability to do away with RF filters thanks to the pass band characteristic of the phase locked loop or PLL. The requirement to have the signals strictly in quadrature is also avoided. Nevertheless, these results are only possible if the voltage controlled oscillator or VCO included in the PLL provides high performance. This is not the case with integrated VCOs. Consequently, the PLL radiofrequency transmitter does not enable a high level of integration to be provided.

Therefore in a general way, these three types of known architecture offer a necessary compromise between integration, consumption and complexity. In other words, none of these three known solutions is entirely satisfactory.

A particular objective of the invention is to remedy these various disadvantages of the state of the technology.

More precisely, one of the objectives of this invention is to provide a radiofrequency transmitter providing good precision and offering a very high degree of integration on silicon.

Another objective of the invention is to provide such a radiofrequency transmitter that has very low sensitivity to the imperfections in the elements that make it up.

Another objective of the invention is to provide such a radiofrequency transmitter that enables one to avoid degradation of the wanted signal.

A complementary objective of the invention is to provide such a radiofrequency transmitter which is simple and is not any more complex than the known architectures.

Another objective of the invention is to provide such a radiofrequency transmitter that allows one to generate a resultant signal that has an image frequency that is sufficiently weak to be able to be suppressed by a filter with relaxed constraints (this filter thus being capable of being integrated).

In an embodiment variation, another objective of the invention is to provide a radiofrequency transmitter that does not give an image frequency, the image frequency at the output being completely attenuated, in an automatic fashion, by a self-calibrating system that compensates for imperfections both in gain and in phase.

These various objectives as well as others that will become apparent below, have been achieved according to the invention by a radiofrequency transmitter, of the type supplied with two signals in baseband and in quadrature, i(nT) and q(nT), which are images from two binary streams representing information to be transmitted, the radiofrequency transmitter comprising:

- means of transposition into an intermediate frequency and of digital processing, that provide a first transposition into the digital domain, at an intermediate frequency ω_0, for said base band signals, and generating, by combination, two signals at the intermediate frequency and in quadrature;

- means of direct conversion, providing a second transposition into the analog domain, after multiplication by a frequency ω_1, followed by a summation, of said two signals at the intermediate frequency and in quadrature, in a way that generates a resultant signal which is finally modulated around a frequency ω_2, where $\omega_2 = \omega_0 + \omega_1$.

Therefore, this invention proposes an original architecture for a radiofrequency transmitter that combines the architectures with direct conversion and with frequency transposition, and which provides, in addition, means of digital processing, which provide preprocessing that permits attenuation at the output of the image frequency introduced by the means of transposition into an intermediate frequency. Hence, this new architecture combines the main advantage of the radiofrequency transmitter with direct conversion (no image frequency) with that of the radiofrequency transmitter with frequency transposition (no degradation of the wanted signal), while at the same time avoiding their disadvantages (sensitivity to imperfections, high performance filter).

In the description that follows, it will be shown that this invention operates perfectly if the two channels of the direct conversion means have the same gain and if the sines and cosines supplied by the oscillator included in the direct conversion means do not suffer from poor quadrature forming.

It will also be shown that, in the contrary case, a low power interference signal appears at the image

frequency, but the wanted signal is not degraded in practice. Consequently, it is not essential to use, at the output, a filter attenuating the image frequency of the wanted signal. In any case, when the performance demanded from the transmission chain requires the use of such a filter, the latter can have relaxed constraints since the image frequency is very attenuated and can therefore be easily suppressed. In other words, the quality of the transmitted signal can be preserved without the need for high image filtering constraints. In certain cases, if the constraints are sufficiently relaxed, the image filter may possibly also be integrated with it.

It should be noted that the first frequency transposition and the signal processing are carried out in the digital domain, which enables one to benefit from the precision and the high degree of integration (on silicon for example).

It will also be noted that the radiofrequency transmitter according to the invention has a high degree of integration (for example, on silicon) and advantageously can even be entirely produced in the form of an integrated circuit. In effect, the means of direct conversion are known for their high degree of silicon integration. Furthermore, the level of integration of the means of transposition into an intermediate frequency can be relatively high since it is not necessary to use high performance filters. Finally, the digital processing means can be reduced to an assembly of elements currently used in integrated systems on silicon, and notably in transmitters with frequency

transposition. This assembly of elements comprises, for example, a Numerically Controlled Oscillator or NCO and linear operators (multipliers and adders).

In addition, the extra complexity compared with a direct conversion architecture is negligible.

Finally, passing through a first intermediate frequency ω_0 generated in the digital domain makes possible the attenuation of any possible leak from the conversion oscillator via the mixers.

In one advantageous embodiment of the invention, said radiofrequency transmitter additionally comprises means of digitally compensating for imperfections in gain and in phase in said means of direct conversion.

Hence, by ensuring that at the output of the radiofrequency transmitter, the signal at the image frequency is completely attenuated, the performance of the radiofrequency transmitter according to the invention is optimized and the resulting transmitted signal has characteristics close to the ideal case. Thanks to this self-calibrating technique of image annulment, the errors introduced by the analog part (that is to say the means of direct conversion) sensitive to the imperfections, are compensated for in the digital domain.

It is important to note that in this particular embodiment, no image frequency filter whatsoever is required. This new architecture for a radiofrequency transmitter therefore operates independently of the chosen carrier frequency and is therefore particularly suitable for multi-standard systems of

radiocommunications. Among the standards possible, one may mention only by way of examples, the Global System for Mobile communications or GSM, the Digital Cellular System 1800 MHz or DCS 1800, the Personal Communication System or PCS 1900, Digital European Cordless Telecommunications or DECT or the Universal Mobile Telecommunication System or UMTS etc..

Preferably, said analog/digital conversion means have a working frequency substantially identical to the working frequency of the digital/analog conversion means in said means of direct conversion.

In a preferred way, said means of digital compensation are included in said integrated circuit. Hence, the radiofrequency transmitter according to this invention can be entirely integrated, for example on silicon.

Other characteristics and advantages of the invention will become apparent on reading the following description of two preferred embodiments of the invention, given by way of examples for information purposes and being non-limitative and accompanied by the appended drawings in which :

- Figure 1 shows a general diagram of a first embodiment of a radiofrequency transmitter according to this invention with "simple" image annulment ; and

- Figure 2 shows a general diagram of a second embodiment of a radiofrequency transmitter according to this invention with "self-calibrating" image annulment.

Therefore the invention relates to a radiofrequency transmitter of the type supplied with two digital signals in baseband and in quadrature i(nT) and q(nT),

which are images of two binary streams representing information to be transmitted. T is the sample period.

In a traditional way, and whatever the digital modulation used, one is seeking to provide a signal to be transmitted m(t) that can be written :

$$m(t) = i(t).\cos(\omega t) - q(t).\sin(\omega t).$$

where ω (= $2\pi f$), the frequency of transmission of the signal (also called the carrier frequency).

1. FIRST EMBODIMENT : "SIMPLE" IMAGE ANNULMENT

1.1 PRESENTATION OF THE ARCHITECTURE

A first embodiment of a radiofrequency transmitter according to this invention will now be described making reference to Figure 1.

In this first embodiment, the radiofrequency transmitter comprises means 1 of transposition into an intermediate frequency and of digital processing and means 2 of direct conversion.

The means 1 of transposition into an intermediate frequency and of digital processing generate two signals $m_1(t)$ and $m_2(t)$ at an intermediate frequency ω_0 and in quadrature. They comprise:

- a numerically controlled oscillator NCO (not shown) at an intermediate frequency ω_0, supplying the following signals : $\cos(\omega_0.nT)$ and $\sin(\omega_0.nT)$;
- four multipliers 3_1 to 3_4; and
- two adders 4_1 to 4_2.

The multipliers 3_1 to 3_4 and the adders 4_1 and 4_2 are fitted in such a way that the signals $m_1(nT)$ and $m_2(nT)$ are of the form:

$$m_1(nT) = i(nT).\cos(\omega_0.nT) - q(nT).\sin(\omega_0.nT)$$

$$m_2(nT) = -i(nT).\sin(\omega_0.nT) - q(nT).\cos(\omega_0.nT)$$

The means 2 of direct conversion generate a resultant signal m(t). They comprise:

- on each of the two channels in quadrature, a digital/analog converter (CNA) 5_1, 5_2 and a high-stop filter 6_1, 6_2, that permits the conversion of the two digital signals $m_1(nT)$ and $m_2(nT)$ into two analog signals $m_1(t)$ and $m_2(t)$;
- a conversion oscillator 7 at a transmission frequency ω_1, supplying the following signals : $\cos(\omega_1.t)$ and $\sin(\omega_1.t)$;
- two multipliers 8_1 and 8_2;
- one adder 9.

The multipliers 8_1 and 8_2 and the adder 9 are fitted in such a way that the resultant signal m(t) is of the form:

$$m(t)=g_1.m_1(t).\cos(\omega_1 t+\theta_1)+g_2.m_2(t).\sin(\omega_1 t+\theta_2)$$

where g_1 and g_2 are the respective gains of the two channels in quadrature of the means 2 of direct conversion, and θ_1 and θ_2 are the respective phase shifts of the two channels in quadrature of the means 2 of direct conversion.

As may be found in detail in the description below, it is shown that the resultant signal is finally modulated around a frequency $\omega_2 (= \omega_0 + \omega_1)$.

Optionally, a filter 17 at the image frequency $\omega_2(=\omega_0+\omega_1)$, can be placed at the output from the radiofrequency transmitter. This filter 17 may possibly also be included in the integrated circuit in which form the radiofrequency transmitter is produced.

1.2 DESCRIPTION OF THE IDEAL CASE

Therefore, the principle consists of generating two signals $m_1(t)$ and $m_2(t)$ made up of the two channels in quadrature $i(t)$ and $q(t)$.

$$m_1(t)=i(t).\cos(\omega_0 t)-q(t).\sin(\omega_0 t)$$

$$m_2(t)=-i(t).\sin(\omega_0 t)-q(t).\cos(\omega_0 t) \quad (2)$$

where $\omega_0(=2\pi f_0)$ is the first intermediate frequency generated in the digital domain.

Next, the means 2 of direct conversion transpose the two signals around the carrier frequency ω_1 by multiplying them by $\sin(\omega_1 t+\phi)$ and $\cos(\omega_1 t+\phi)$.

The resultant signal $m(t)$ is written in the following way:

$$m(t)=m_1(t).\cos(\omega_1 t+\phi)+m_2(t).\sin(\omega_1 t+\phi)$$

$$=i(t).\cos(\omega_0 t+\omega_1 t+\phi)-q(t).\sin(\omega_0 t+\omega_1 t+\phi) \quad (3)$$

$$m(t)=i(t).\cos(\omega_2 t+\phi)-q(t).\sin(\omega_2 t+\phi) \quad (4)$$

A signal is obtained modulated around the carrier $\omega_2=\omega_0+\omega_1$, the particular feature of which is not to have an image frequency around ω_1. The resultant formula in equation (4) is verified for the ideal case where the transmitter with direct conversion has perfect characteristics. Unfortunately, this is rarely the case.

1.3 DESCRIPTION OF THE REAL CASE

Taking the imperfections into account, the resultant transmitted signal m(t) is written:

$$m(t)=g_1.m_1(t).\cos(\omega_1 t+\theta_1)+g_2.m_2(t).\sin(\omega_1 t+\theta_2) \qquad (5)$$

Equation (2) enables one to write equation (5) that includes i(t) and q(t):

$$m(t) = i(t).[g_1.\cos\omega_0 t.\cos(\omega_1 t+\theta_1) - g_2.\sin\omega_0 t.\sin(\omega_1 t+\theta_2)]$$
$$- q(t).[g_1.\sin\omega_0 t.\cos(\omega_1 t+\theta_1) + g_2.\cos\omega_0 t.\sin(\omega_1 t+\theta_2)]$$

$$m(t) = \frac{i(t)}{2}\begin{Bmatrix} g_1\left[\cos(\omega_0 t-\omega_1 t-\theta_1)+\cos(\omega_0 t+\omega_1 t+\theta_1)\right] \\ -g_2[\cos(\omega_0 t-\omega_1 t-\theta_2)-\cos(\omega_0 t+\omega_1 t+\theta_2)] \end{Bmatrix}$$
$$-\frac{q(t)}{2}\begin{Bmatrix} g_1[\sin(\omega_0 t-\omega_1 t-\theta_1)+\sin(\omega_0 t+\omega_1 t+\theta_1)] \\ -g_2[\sin(\omega_0 t-\omega_1 t-\theta_2)-\sin(\omega_0 t+\omega_1 t+\theta_2)] \end{Bmatrix} \qquad (6)$$

$$m(t) = \frac{i(t)}{2}\begin{Bmatrix} g_1.\cos(\omega_0 t-\omega_1 t-\theta_1)-g_2.\cos(\omega_0 t-\omega_1 t-\theta_2) \\ +g_1.\cos(\omega_0 t+\omega_1 t+\theta_1)+g_2.\cos(\omega_0 t+\omega_1 t+\theta_2) \end{Bmatrix}$$
$$-\frac{q(t)}{2}\begin{Bmatrix} g_1.\sin(\omega_0 t-\omega_1 t-\theta_1)-g_2.\sin(\omega_0 t-\omega_1 t-\theta_2) \\ +g_1.\sin(\omega_0 t+\omega_1 t+\theta_1)+g_2.\sin(\omega_0 t+\omega_1 t+\theta_2) \end{Bmatrix}$$

In order to simplify the result described by equation (6) we can replace :

$$\left.\begin{aligned} \theta_1 &= \theta-\frac{\Delta\theta}{2} \\ \theta_2 &= \theta+\frac{\Delta\theta}{2} \end{aligned}\right\} \text{ with } \theta=\frac{\theta_1+\theta_2}{2} \text{ and}$$

$$\left.\begin{aligned} g_1 &= g-\frac{\Delta g}{2} \\ g_2 &= g+\frac{\Delta g}{2} \end{aligned}\right\} \text{ with } g=\frac{g_1+g_2}{2} \qquad (7)$$

which means that m(t) can be expressed in the form:

$$
\begin{aligned}
m(t) = \frac{i(t)}{2}&\left\{\begin{array}{l}
g.\left[\cos\left(\omega_0 t - \omega_1 t - \theta + \frac{\Delta\theta}{2}\right) - \cos\left(\omega_0 t - \omega_1 t - \theta - \frac{\Delta\theta}{2}\right)\right] \\
-\frac{\Delta g}{2}\left[\cos\left(\omega_0 t - \omega_1 t - \theta + \frac{\Delta\theta}{2}\right) + \cos\left(\omega_0 t - \omega_1 t - \theta - \frac{\Delta\theta}{2}\right)\right] \\
+g.\left[\cos\left(\omega_0 t + \omega_1 t + \theta - \frac{\Delta\theta}{2}\right) + \cos\left(\omega_0 t + \omega_1 t + \theta + \frac{\Delta\theta}{2}\right)\right] \\
-\frac{\Delta g}{2}\left[\cos\left(\omega_0 t + \omega_1 t + \theta - \frac{\Delta\theta}{2}\right) - \cos\left(\omega_0 t + \omega_1 t + \theta + \frac{\Delta\theta}{2}\right)\right]
\end{array}\right\} \\
-\frac{q(t)}{2}&\left\{\begin{array}{l}
g.\left[\sin\left(\omega_0 t - \omega_1 t - \theta + \frac{\Delta\theta}{2}\right) - \sin\left(\omega_0 t - \omega_1 t - \theta - \frac{\Delta\theta}{2}\right)\right] \\
-\frac{\Delta g}{2}\left[\sin\left(\omega_0 t - \omega_1 t - \theta + \frac{\Delta\theta}{2}\right) + \sin\left(\omega_0 t - \omega_1 t - \theta - \frac{\Delta\theta}{2}\right)\right] \\
+g.\left[\sin\left(\omega_0 t + \omega_1 t + \theta - \frac{\Delta\theta}{2}\right) + \sin\left(\omega_0 t + \omega_1 t + \theta + \frac{\Delta\theta}{2}\right)\right] \\
-\frac{\Delta g}{2}\left[\sin\left(\omega_0 t + \omega_1 t + \theta - \frac{\Delta\theta}{2}\right) - \sin\left(\omega_0 t + \omega_1 t + \theta + \frac{\Delta\theta}{2}\right)\right]
\end{array}\right\} \quad (8)
\end{aligned}
$$

$$
\begin{aligned}
m(t) = i(t)&\left\{\begin{array}{l}
-g.\sin(\omega_0 t - \omega_1 t - \theta)\sin\left(\frac{\Delta\theta}{2}\right) - \frac{\Delta g}{2}\cos(\omega_0 t - \omega_1 t - \theta).\cos\left(\frac{\Delta\theta}{2}\right) \\
+g.\cos(\omega_0 t + \omega_1 t + \theta)\sin\left(\frac{\Delta\theta}{2}\right) - \frac{\Delta g}{2}\sin(\omega_0 t + \omega_1 t + \theta).\sin\left(\frac{\Delta\theta}{2}\right)
\end{array}\right\} \\
-q(t)&\left\{\begin{array}{l}
g.\cos(\omega_0 t - \omega_1 t - \theta)\sin\left(\frac{\Delta\theta}{2}\right) - \frac{\Delta g}{2}.\sin(\omega_0 t - \omega_1 t - \theta).\cos\left(\frac{\Delta\theta}{2}\right) \\
+g.\sin(\omega_0 t + \omega_1 t + \theta)\cos\left(\frac{\Delta\theta}{2}\right) + \frac{\Delta g}{2}.\cos(\omega_0 t + \omega_1 t + \theta).\sin\left(\frac{\Delta\theta}{2}\right)
\end{array}\right\} \quad (9)
\end{aligned}
$$

By bringing in the carrier frequency $\omega_2 = \omega_1 + \omega_0$ and its image frequency $\omega_{-2} = \omega_1 - \omega_0$:

$$
m(t) = i(t)\left\{\begin{array}{l}
g.\sin(\omega_{-2} t + \theta)\sin\left(\frac{\Delta\theta}{2}\right) - \frac{\Delta g}{2}.\cos(\omega_{-2} t + \theta)\cos\left(\frac{\Delta\theta}{2}\right) \\
+g.\cos(\omega_2 t + \theta)\cos\left(\frac{\Delta\theta}{2}\right) - \frac{\Delta g}{2}.\sin(\omega_2 t + \theta)\sin\left(\frac{\Delta\theta}{2}\right)
\end{array}\right\} \quad (10)
$$

$$-q(t)\left\{\begin{aligned}&g.\cos(\omega_{-2}t+\theta)\sin\left(\frac{\Delta\theta}{2}\right)+\frac{\Delta g}{2}.\sin(\omega_{-2}t+\theta)\cos\left(\frac{\Delta\theta}{2}\right)\\&+g.\sin(\omega_2 t+\theta)\cos\left(\frac{\Delta\theta}{2}\right)+\frac{\Delta g}{2}.\cos(\omega_2 t+\theta)\sin\left(\frac{\Delta\theta}{2}\right)\end{aligned}\right\}$$

$$\begin{aligned}m(t)=\ &g.\cos\left(\frac{\Delta\theta}{2}\right).\left[i(t).\cos(\omega_2 t+\theta)-q(t).\sin(\omega_2 t+\theta)\right]\\&-\frac{\Delta g}{2}.\sin\left(\frac{\Delta\theta}{2}\right).\left[i(t).\sin(\omega_2 t+\theta)+q(t).\cos(\omega_2 t+\theta)\right]\\&+g.\sin\left(\frac{\Delta\theta}{2}\right).\left[i(t).\sin(\omega_{-2}t+\theta)-q(t).\cos(\omega_{-2}t+\theta)\right]\\&-\frac{\Delta g}{2}.\cos\left(\frac{\Delta\theta}{2}\right).\left[i(t).\cos(\omega_{-2}t+\theta)+q(t).\sin(\omega_{-2}t+\theta)\right]\end{aligned}\qquad(11)$$

The resultant signal m(t) is therefore constituted by :

- a wanted signal (modulated about the carrier ω_2), weighted by a gain equal to $g.\cos\left(\frac{\Delta\theta}{2}\right)$;

- an undesirable component, whose amplitude is of the order of $\frac{\Delta g}{2}.\sin\left(\frac{\Delta\theta}{2}\right)$;

- an image in ω_{-2} (due to the imperfections), the power of which depends on the difference in gain Δg and in phase $\Delta\theta$ between the two channels.

The result from equation (11) shows that the imperfections in gain and in phase generate a parasite component in ω_2 of power sufficiently low to be easily filtered. Contrary to this, the imperfections have very little influence on the quality of the wanted signal.

If a gain error Δg = 3% and a phase error (quadrature) $\Delta\theta = 3°$ are chosen, the C/I of the wanted signal (power of the signal / power of the interference at frequency ω_2) is 68 dBc, instead of 28 dBc for an architecture with traditional direct conversion. The power level of the interference present at the image frequency ω_{-2} is about 28 dB below the wanted signal while it would be 25 times higher with a traditional frequency transposition structure.

Compared to the other architectures, this original system offers the following advantages:

- an identical gain for the channels i(t) and q(t);
- negligible degradation of the wanted signal ($\approx\Delta g.\Delta\theta/4$);
- a highly attenuated image frequency which can be suppressed with a relaxed constraint filter;
- reduced complexity compared with a direct conversion transmitter thanks to signal processing being carried out in the digital domain.

Furthermore, passing through a first intermediate frequency FI(ω_0) generated in the digital domain enables one to attenuate any possible leakage from the conversion oscillator via the mixers.

2. SECOND EMBODIMENT : "SELF-CALIBRATING" IMAGE ANNULMENT

2.1 DESCRIPTION OF THE ARCHITECTURE

A second embodiment of a radiofrequency transmitter according to this invention will now be described with reference to Figure 2.

In effect, in order to go further with the radiofrequency transmitter according to the invention it is proposed that gain and phase errors introduced in the direct conversion means 2 be compensated for digitally. Hence, at the output, the signal present at the image frequency will be completely attenuated.

This second embodiment differs from the first embodiment (described above with reference to Figure 1) in that it additionally comprises means 10, 11 of digitally compensating for imperfections in gain Δg and in phase $\Delta\theta$ of the direct conversion means 2. These compensation means themselves comprise means 10 of estimating the imperfections Δg and $\Delta\theta$, and means 11 of applying a correction to the two signals $m_1(t)$ and $m_2(t)$ in a way that generates two corrected signals $m_{1c}(t)$ and $m_{2c}(t)$.

In the embodiment shown in Figure 2, the means 10 of estimating the imperfections comprise :

- transposition means 12, providing a third transposition in the analog domain, by multiplication of the resultant signal m(t) by the transmission frequency ω_1, in a way that generates an intermediate signal : $m'_3(t)=g_3.m(t).\cos(\omega_1 t+\theta_1)$, where g_3 is the gain introduced by the transposition means 12, the filtering means 13 and the analog/digital A/N conversion means 14.

- a high stop filter 13, providing filtering of the intermediate signal $m'_3(t)$ and generating an intermediate filtered signal $m'(t)$;

- an analog/digital converter (CAN) 14, enabling one to convert the intermediate filtered signal $m'(t)$ into digital;

- means 15 of calculating imperfections in gain Δg and in phase $\Delta\theta$ from the digital filtered intermediate signal $m'(t)$.

It should be noted that the means 1 of transposition into intermediate frequency and of digital processing, the means 15 of calculating the imperfections and the means 11 of applying a correction to the two signals $m_1(t)$ and $m_2(t)$ can be included in one and the same digital signal processor (or DSP) 16.

The operation of this second embodiment of the radiofrequency transmitter can be broken down into three successive phases, namely;

- recovery of the resultant transmitted signal $m(t)$;

- calculation of the correction coefficients Δg and $\Delta\theta$;

- calculation of the resultant corrected signal $m_c(t)$.

Theses three phases will now be described in succession, in paragraphs 2.2 to 2.4 respectively.

1.2 RECOVERY OF THE RESULTANT TRANSMITTED SIGNAL

The resultant signal m(t) is multiplied by the frequency ω_1 of the conversion oscillator 7 (the latter is included in the direct conversion means 2). Hence m(t) is transposed to a lower fixed frequency, before analog/digital conversion.

The resultant signal is written :

$$m'_3(t) = g_3.m(t).\cos\left(\omega_1 t + \theta - \frac{\Delta\theta}{2}\right)$$

By developing the product above and assuming that $g_3=1$, $m'_3(t)$ becomes:

$$\begin{aligned}
m_3'(t) = {} & g.\cos\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l} \frac{i(t)}{2}\left[\cos\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + \cos\left(2\omega_1 t + \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right] \\ -\frac{q(t)}{2}\left[\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + \sin\left(2\omega_1 t + \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right]\end{array}\right\} \\
& -\frac{\Delta g}{2}.\sin\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l} \frac{i(t)}{2}\left[\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + \sin\left(2\omega_1 t + \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right] \\ +\frac{q(t)}{2}\left[\cos\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + \cos\left(2\omega_1 t + \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right]\end{array}\right\} \\
& +g.\sin\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l} \frac{i(t)}{2}\left[\sin\left(-\omega_0 t + \frac{\Delta\theta}{2}\right) + \sin\left(2\omega_1 t - \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right] \\ -\frac{q(t)}{2}\left[\cos\left(-\omega_0 t + \frac{\Delta\theta}{2}\right) + \cos\left(2\omega_1 t - \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right]\end{array}\right\} \\
& -\frac{\Delta g}{2}.\cos\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l} \frac{i(t)}{2}\left[\cos\left(-\omega_0 t + \frac{\Delta\theta}{2}\right) + \cos\left(2\omega_1 t - \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right] \\ +\frac{q(t)}{2}\left[\sin\left(-\omega_0 t + \frac{\Delta\theta}{2}\right) + \sin\left(2\omega_1 t - \omega_0 t + 2\theta - \frac{\Delta\theta}{2}\right)\right]\end{array}\right\}
\end{aligned}$$

(12)

The high stop filtering (filter 13) suppresses the components $2\omega_1 t \pm \omega_0 t$ and gives :

$$m'(t) = g.\cos\left(\frac{\Delta\theta}{2}\right).\left[\frac{i(t)}{2}.\cos\left(\omega_0 t + \frac{\Delta\theta}{2}\right) - \frac{q(t)}{2}.\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right)\right]$$

$$-\frac{\Delta g}{2}\sin\left(\frac{\Delta\theta}{2}\right).\left[\frac{i(t)}{2}\sin\left(\omega_0 t+\frac{\Delta\theta}{2}\right)+\frac{q(t)}{2}\cos\left(\omega_0 t+\frac{\Delta\theta}{2}\right)\right]$$

(13)

$$-g.\sin\left(\frac{\Delta\theta}{2}\right).\left[\frac{i(t)}{2}\sin\left(\omega_0 t-\frac{\Delta\theta}{2}\right)+\frac{q(t)}{2}\cos\left(\omega_0 t-\frac{\Delta\theta}{2}\right)\right]$$

$$-\frac{\Delta g}{2}\cos\left(\frac{\Delta\theta}{2}\right).\left[\frac{i(t)}{2}\cos\left(\omega_0 t-\frac{\Delta\theta}{2}\right)-\frac{q(t)}{2}\sin\left(\omega_0 t-\frac{\Delta\theta}{2}\right)\right]$$

$$m'(t)=g.\cos\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l}\frac{i(t)}{2}\left[\cos(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)-\sin(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\\-\frac{q(t)}{2}\left[\sin(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)+\cos(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\end{array}\right\}$$

$$-\frac{\Delta g}{2}.\sin\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l}\frac{i(t)}{2}\left[\sin(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)+\cos(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\\+\frac{q(t)}{2}\left[\cos(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)-\sin(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\end{array}\right\}$$

$$-g.\sin\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l}\frac{i(t)}{2}\left[\sin(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)-\cos(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\\+\frac{q(t)}{2}\left[\cos(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)+\sin(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\end{array}\right\}$$

$$-\frac{\Delta g}{2}.\cos\left(\frac{\Delta\theta}{2}\right).\left\{\begin{array}{l}\frac{i(t)}{2}\left[\cos(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)+\sin(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\\-\frac{q(t)}{2}\left[\sin(\omega_0 t)\cos\left(\frac{\Delta\theta}{2}\right)-\cos(\omega_0 t)\sin\left(\frac{\Delta\theta}{2}\right)\right]\end{array}\right\} \quad (14)$$

$$m'(t)=g.\left\{\begin{array}{l}\frac{i(t)}{2}\left[\cos(\omega_0 t)\cos^2\left(\frac{\Delta\theta}{2}\right)-\sin(\omega_0 t)\frac{\sin(\Delta\theta)}{2}\right]\\-\frac{q(t)}{2}\left[\sin(\omega_0 t)\cos^2\left(\frac{\Delta\theta}{2}\right)+\cos(\omega_0 t)\frac{\sin(\Delta\theta)}{2}\right]\end{array}\right\}$$

$$
\begin{aligned}
&-\frac{\Delta g}{2}\left\{\begin{array}{l}\dfrac{i(t)}{2}\left[\sin(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}+\cos(\omega_0 t)\sin^2\left(\dfrac{\Delta\theta}{2}\right)\right]\\+\dfrac{q(t)}{2}\left[\cos(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}-\sin(\omega_0 t)\sin^2\left(\dfrac{\Delta\theta}{2}\right)\right]\end{array}\right\}\\
&-g\left\{\begin{array}{l}\dfrac{i(t)}{2}\left[\sin(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}-\cos(\omega_0 t)\sin^2\left(\dfrac{\Delta\theta}{2}\right)\right]\\+\dfrac{q(t)}{2}\left[\cos(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}+\sin(\omega_0 t)\sin^2\left(\dfrac{\Delta\theta}{2}\right)\right]\end{array}\right\}\\
&-\frac{\Delta g}{2}\left\{\begin{array}{l}\dfrac{i(t)}{2}\left[\cos(\omega_0 t)\cos^2\left(\dfrac{\Delta\theta}{2}\right)+\sin(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}\right]\\-\dfrac{q(t)}{2}\left[\sin(\omega_0 t)\cos^2\left(\dfrac{\Delta\theta}{2}\right)-\cos(\omega_0 t)\dfrac{\sin(\Delta\theta)}{2}\right]\end{array}\right\}
\end{aligned}
\tag{15}
$$

$$
\begin{aligned}
m'(t) = {} & g.\left\{\frac{i(t)}{2}.\left[\cos(\omega_0 t)-\sin(\omega_0 t)\sin(\Delta\theta)\right]-\frac{q(t)}{2}.\left[\sin(\omega_0 t)+\cos(\omega_0 t)\sin(\Delta\theta)\right]\right\}\\
& -\frac{\Delta g}{2}.\left\{\frac{i(t)}{2}.\left[\cos(\omega_0 t)+\sin(\omega_0 t)\sin(\Delta\theta)\right]-\frac{q(t)}{2}.\left[\sin(\omega_0 t)-\cos(\omega_0 t)\sin(\Delta\theta)\right]\right\}
\end{aligned}
\tag{16}
$$

$$
\begin{aligned}
m'(t) = {} & \left\{\frac{i(t)}{2}.\left[g-\frac{\Delta g}{2}\right]-\frac{q(t)}{2}\left[g+\frac{\Delta g}{2}\right]\sin(\Delta\theta)\right\}.\cos(\omega_0 t)\\
& -\left\{\frac{i(t)}{2}.\left[g+\frac{\Delta g}{2}\right]\sin(\Delta\theta)+\frac{q(t)}{2}\left[g-\frac{\Delta g}{2}\right]\right\}.\sin(\omega_0 t)
\end{aligned}
\tag{17}
$$

$$
m'(t) = i'(t).\cos(\omega_0 t) - q'(t).\sin(\omega_0 t) \quad \text{with} \quad \left\{\begin{array}{l} i'(t) = a.i(t) - b.q(t) \\ q'(t) = b.i(t) + a.q(t) \end{array}\right.
\tag{18}
$$

$$
a = \frac{2g-\Delta g}{4}, \qquad b = \frac{2g+\Delta g}{4}\sin(\Delta\theta)
$$

From equation (18), one seeks to extract the coefficients 'a' and 'b' so as to deduce from it the values of Δg and $\Delta\theta$. Knowing that $i^2(t)+q^2(t)=1$, one has

$$\begin{aligned} a &= i(t).i'(t) + q(t).q'(t) \\ b &= i(t).q'(t) - q(t).i'(t) \end{aligned} \tag{19}$$

In the real case where $g_3 \neq 0$, the coefficients 'a' and 'b' are written:

$$a = g_3.\frac{2g - \Delta g}{4} \quad \text{and} \quad b = g_3.\frac{2g + \Delta g}{4}\sin\Delta\theta \tag{20}$$

1.3 CALCULATION OF THE CORRECTION COEFFICIENTS

Knowing the theoretical values of the gains 'g' and 'g_3', one can calculate Δg, $\Delta\theta$ and the real value of g_3 from the coefficients 'a' and 'b'. Equation (20) gives us:

$$a + b = \frac{g_3}{4}\left[2g(1+\sin\Delta\theta) - \Delta g(1-\sin\Delta\theta)\right] \tag{21}$$

Assuming that, in a first approximation, $\sin\Delta\theta \approx 0$ and $\Delta g \ll g$, an estimation of the gain g_3 can be deduced:

$$g'_3 = \frac{2(a+b)}{g} = \frac{2}{g}\left[i'(t) + q'(t)\right]\left[i(t) - q(t)\right] \tag{22}$$

On keeping the approximation $\sin\Delta\theta \approx 0$ and knowing the theoretical value for g_3, one can rapidly determine Δg:

$$\Delta g \approx \frac{2g}{g_3}\left(g_3 - g'_3\right) = 2g - \frac{4}{g_3}\left[i'(t) + q'(t)\right]\left[i(t) - q(t)\right] \tag{23}$$

On introducing the gain calculated in (22), the coefficient $\Delta\theta$ is deduced from equation (20) with the hypothesis that $\sin\Delta\theta \approx \Delta\theta$ and $\Delta g.\sin\Delta\theta \approx 0$:

$$\Delta\theta \approx \frac{b}{g.g_3} = \frac{1}{g.g_3}\left[i(t).q'(t) - q(t).i'(t)\right] \qquad (24)$$

By choosing values to the value 2 for the theoretical gains 'g' and 'g3', the calculation of the correction coefficients is simplified, avoiding an expensive division in silicon.

<u>1.4 CALCULATION OF THE RESULTANT CORRECTED SIGNAL</u>

After calculation of the correction coefficients Δg and $\Delta\theta$, the new corrected transmission signal $m_c(t)$ must be constructed:

$$m_c(t) = m_{1c}(t).\left(g - \frac{\Delta g}{2}\right)\cos\left(\omega_1 t + \theta - \frac{\Delta\theta}{2}\right) + m_{2c}(t).\left(g + \frac{\Delta g}{2}\right)\sin\left(\omega_1 t + \theta + \frac{\Delta\theta}{2}\right) \qquad (25)$$

where $m_{1c}(t)$ and $m_{2c}(t)$ are the two channels corrected for gain and phase:

$$m_{1c}(t) = \frac{1}{\left(1 - \frac{\Delta g}{2g}\right)}\left[i(t).\cos\left(\omega_0 t - \frac{\Delta\theta}{2}\right) - q(t).\sin\left(\omega_0 t - \frac{\Delta\theta}{2}\right)\right]$$

$$(26)$$

$$m_{2c}(t) = \frac{-1}{\left(1 + \frac{\Delta g}{2g}\right)}\left[i(t).\cos\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + q(t).\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right)\right]$$

By developing equation (25) one arrives at:

$$m_c(t) = i(t).\cos\left(\omega_1 t + \theta - \frac{\Delta\theta}{2}\right).\cos\left(\omega_1 t - \frac{\Delta\theta}{2}\right) - q(t).\cos\left(\omega_1 t + \theta - \frac{\Delta\theta}{2}\right).\sin\left(\omega_1 t - \frac{\Delta\theta}{2}\right) \qquad (27)$$

$$- i(t).\sin\left(\omega_1 t + \theta + \frac{\Delta\theta}{2}\right).\sin\left(\omega_1 t + \frac{\Delta\theta}{2}\right) - q(t).\sin\left(\omega_1 t + \theta + \frac{\Delta\theta}{2}\right).\cos\left(\omega_1 t + \frac{\Delta\theta}{2}\right)$$

$$\begin{aligned} m_c(t) = {} & \frac{i(t)}{2}\left[\cos(\omega_1 t - \omega_0 t + \theta) + \cos(\omega_1 t + \omega_0 t + \theta - \Delta\theta)\right] \\ & + \frac{q(t)}{2}\left[\sin(\omega_1 t - \omega_0 t + \theta) - \sin(\omega_1 t + \omega_0 t + \theta - \Delta\theta)\right] \\ & - \frac{i(t)}{2}\left[\cos(\omega_1 t - \omega_0 t + \theta) - \cos(\omega_1 t + \omega_0 t + \theta + \Delta\theta)\right] \\ & - \frac{q(t)}{2}\left[\sin(\omega_1 t - \omega_0 t + \theta) + \sin(\omega_1 t + \omega_0 t + \theta + \Delta\theta)\right] \end{aligned} \qquad (28)$$

$$\begin{aligned} m_c(t) = {} & \frac{i(t)}{2}\left[\cos(\omega_1 t + \omega_0 t + \theta - \Delta\theta) + \cos(\omega_1 t + \omega_0 t + \theta + \Delta\theta)\right] \\ & - \frac{q(t)}{2}\left[\sin(\omega_1 t + \omega_0 t + \theta - \Delta\theta) + \sin(\omega_1 t + \omega_0 t + \theta + \Delta\theta)\right] \end{aligned} \qquad (29)$$

$$m_c(t) = \left[i(t)\cos(\omega_1 t + \omega_0 t + \theta) - q(t)\sin(\omega_1 t + \omega_0 t + \theta)\right]\cos\Delta\theta \qquad (30)$$

By again substituting $\omega_2 = \omega_1 + \omega_0$, one again finds the expression for the signal m(t) formulated in the ideal case (equation 4), with g = 1). The correction system is simplified without degrading the signal quality since this again is applied to both channels i(t) and q(t). If $\Delta\theta = 5°$, the resultant error is about 0.4% on the amplitude of the transmitted signal.

The simplified expression for the two channels $m_{1c}(t)$ and $m_{2c}(t)$ corrected for gain and for phase is written:

$$m_{1c}(t) = \left(1 + \frac{\Delta g}{2g}\right).\left[i(t).\cos\left(\omega_0 t - \frac{\Delta\theta}{2}\right) - q(t).\sin\left(\omega_0 t - \frac{\Delta\theta}{2}\right)\right]$$

$$m_{2c}(t) = -\left(1 - \frac{\Delta g}{2g}\right).\left[i(t).\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right) + q(t).\sin\left(\omega_0 t + \frac{\Delta\theta}{2}\right)\right] \quad (31)$$

In other words the means 11 of applying a correction to the two signals $m_1(t)$ and $m_2(t)$ apply:

- to the first channel : a gain equal to $(1 + \Delta g/2g)$ and a phase shift equal to $(-\Delta\theta/2)$;
- to the second channel : a gain equal to $(1 - \Delta g/2g)$ and a phase shift equal to $(+\Delta\theta/2)$.

In this way all division operations for the calculation of the corrected signal are avoided ; within the hypothesis where the theoretical value for the gain 'g' is chosen in such a way that it is a multiple of a power of 2.

The algorithms for calculating Δg and $\Delta\theta$ have been successfully simulated : the error is compensated after 5 iterations at the most, according to the orders of magnitude of Δg and $\Delta\theta$ (up to 10% and 8° respectively) and with an error ranging up to 12% on the value of g_3.

Throughout the detailed description above of two particular embodiments, the new architecture of a radiofrequency transmitter according to this invention has been described.

It will be recalled that it combines the advantages of a transmitter with direct conversion (no image frequency) without having its disadvantages (no degradation of the wanted signal). Thanks to the self-calibrating system, the errors, introduced through the analog part sensitive to the imperfections, are compensated for in the digital domain. Hence the

resultant signal which is transmitted has characteristics close to the ideal case.

The signal processing functions are carried out in the digital domain so as to exploit the precision and the high degree of integration on silicon. The analog/digital converter (CAN) 14 is, for example of the "delta-sigma pass band" type, whose working frequency is preferably identical to that of the two digital/analog converters 5_1 and 5_2. The analog high stop filter 13 has relaxed constraints : a filter of order 2 is sufficient in most cases.

The radiofrequency transmitter according to the invention provides relatively low complexity compared with the remainder of the transmission chain and has the advantage of being able to be completely integrated on silicon.

CLAIMS

1. Radiofrequency transmitter, of the type supplied with two signals in baseband and in quadrature, i(nT) and q(nT), which are images from two binary streams representing information to be transmitted, the radiofrequency transmitter characterized in that it comprises:

- means (1) of transposition into an intermediate frequency and of digital processing, that provide a first transposition into the digital domain, at an intermediate frequency ω_0, for said base band signals, and generating, by combination, two signals at the intermediate frequency and in quadrature;

- means (2) of direct conversion, providing a second transposition into the analog domain, after multiplication by a frequency ω_1, followed by a summation, of said two signals at the intermediate frequency and in quadrature, in a way that generates a resultant signal which is finally modulated around a frequency ω_2, where $\omega_2 = \omega_0 + \omega_1$.

2. Radiofrequency transmitter according to Claim 1, characterized in that said two signals at the intermediate frequency and in quadrature are of the form:

* $m_1(t)=i(t).\cos(\omega_0 t)-q(t).\sin(\omega_0 t)$

* $m_2(t)=-i(t).\sin(\omega_0 t)-q(t).\cos(\omega_0 t)$

and in that said resultant signal is of the form

* $m(t)=g_1.m_1(t).\cos(\omega_1 t+\theta_1)+g_2.m_2(t).\sin(\omega_1 t+\theta_2)$

where

- g_1 and g_2 are the respective gains for the two channels in quadrature of said means of direct conversion

- θ_1 and θ_2 are the respective phase shifts for the two channels in quadrature of said means of direct conversion.

3. Radiofrequency transmitter according to any one of Claims 1 and 2 characterized in that it is produced in the form of an integrated circuit.

4. Radiofrequency transmitter according to any one of Claims 1 to 3 characterized in that it additionally comprises filtering means (17) that receive and filter said resultant signal, in a way that suppresses, at least in part, a parasitic component of said resultant signal, at the image frequency ω_{-2} of said frequency ω_2.

5. Radiofrequency transmitter according to Claims 3 and 4, characterized in that, at least a part of said filtering means (17) is included in said integrated circuit.

6. Radiofrequency transmitter according to any one of Claims 1 to 5, characterized in that it additionally comprises means (10, 11) of digitally compensating for imperfections in gain and in phase of said means of direct conversion.

7. Radiofrequency transmitter according to Claim 6, characterized in that, said means of digital compensation comprise:

- means (10) of estimating the imperfections in gain Δg and in phase $\Delta\theta$ of said means of direct conversion with,
  * $\Delta g = g_2 - g_1$
  * $\Delta\theta = \theta_2 - \theta_1$
- means (11) of applying a correction to said two signals at the intermediate frequency and in quadrature, in a way that generates two corrected signals, $m_{1c}(t)$ and $m_{2c}(t)$ at the intermediate frequency and in quadrature, the corresponding resultant corrected signal being written:

* $m_c(t) = g_1.m_{1c}(t).\cos(\omega_1 t + \theta_1) + g_2.m_{2c}(t).\sin(\omega_1 t + \theta_2)$

8. Radiofrequency transmitter according to Claim 7, characterized in that, said means (10) of estimating imperfections comprise:

- transposition means (12), that provide a third transposition in the analog domain, by multiplication of the resultant signal by said transmission frequency ω_1, in a way that generates the following intermediate signal :

* $m'_3(t)=g_3.m(t).\cos(\omega_1 t+\theta_1)$,

where g_3 is the gain introduced by said transposition means (12), said filtering means (13) and said analog/digital A/N conversion means (14).

- high stop filtering means (13), providing filtration of the intermediate signal and generating an intermediate filtered signal m'(t);

- analog/digital conversion means (14), enabling one to convert the intermediate filtered signal m'(t) into digital;

- means (15) of calculating imperfections in gain Δg and in phase $\Delta\theta$ from the digital filtered intermediate signal by said means of analog/digital conversion.

9. Radiofrequency transmitter according to Claim 8, characterized in that, said means (15) of calculating imperfections in gain Δg and in phase $\Delta\theta$ comprise:

- means of transforming said digital filtered intermediate signal in the form:

* $m'(t) = I'(t).\cos(\omega_0 t) - q'(t).\sin(\omega_0 t)$

and in that the imperfections in gain Δg and in phase $\Delta\theta$ are estimated in accordance with the following formulae;

* $\Delta g = 2g - (4/g_3).[i'(t)+q'(t)].[i(t)-q(t)]$

* $\Delta\theta = (1/g.g_3).[i(t).q'(t)-q(t).i'(t)]$.

10. Radiofrequency transmitter according to any one of Claims 8 and 9, characterized in that said gains g and g_3 have values of power 2.

11. Radiofrequency transmitter according to any one of Claims 7 to 10, characterized in that said two corrected signals, at the intermediate frequency and in

quadrature, are written in the following simplified form:

* $m_{1c}(t)=(1+(\Delta g/2g)).[i(t).\cos(\omega_0 t-(\Delta\theta/2))-q(t).\sin(\omega_0 t-(\Delta\theta/2))]$

* $m_{2c}(t)=-(1-(\Delta g/2g)).[i(t).\sin(\omega_0 t+(\Delta\theta/2))-q(t).\cos(\omega_0 t+(\Delta\theta/2))]$

12. Radiofrequency transmitter according to any one of Claims 6 to 11, characterized in that said means (14) of analog/digital conversion have a working frequency substantially identical to the working frequency of means (5_1, 5_2) of digital/analog conversion included in said means (2) of direct conversion.

13. Radiofrequency transmitter according to Claim 3 and any one of Claims 6 to 12, characterized in that said means (10, 11) of digital compensation are included in said integrated circuit.

ABSTRACT OF THE DISCLOSURE

RADIOFREQUENCY TRANSMITTER WITH A HIGH DEGREE OF INTEGRATION AND POSSIBLY WITH SELF-CALIBRATING IMAGE DELETION

The invention relates to a radiofrequency transmitter, of the type supplied with two signals in baseband and in quadrature, i(nT) and q(nT), which are images from two binary streams representing information to be transmitted.

According to the invention, the radiofrequency transmitter comprises : means (1) of transposition into an intermediate frequency and digital processing, providing a first transposition into the digital domain, at an intermediate frequency ω_0, for said baseband signals, and generating, by combination, two signals of intermediate frequency in quadrature; means (2) of direct conversion, providing a second transposition into the analog domain, after multiplication by a frequency ω_1, followed by a summation of said two signals at intermediate frequency and in quadrature, in such a way that a resultant signal is generated which is found finally around a frequency ω_2, where $\omega_2 = \omega_0 + \omega_1$.

In an advantageous variant, the radiofrequency transmitter additionally comprises means of digitally compensating gain and phase imperfections in said means of direct conversion.

FIG.1

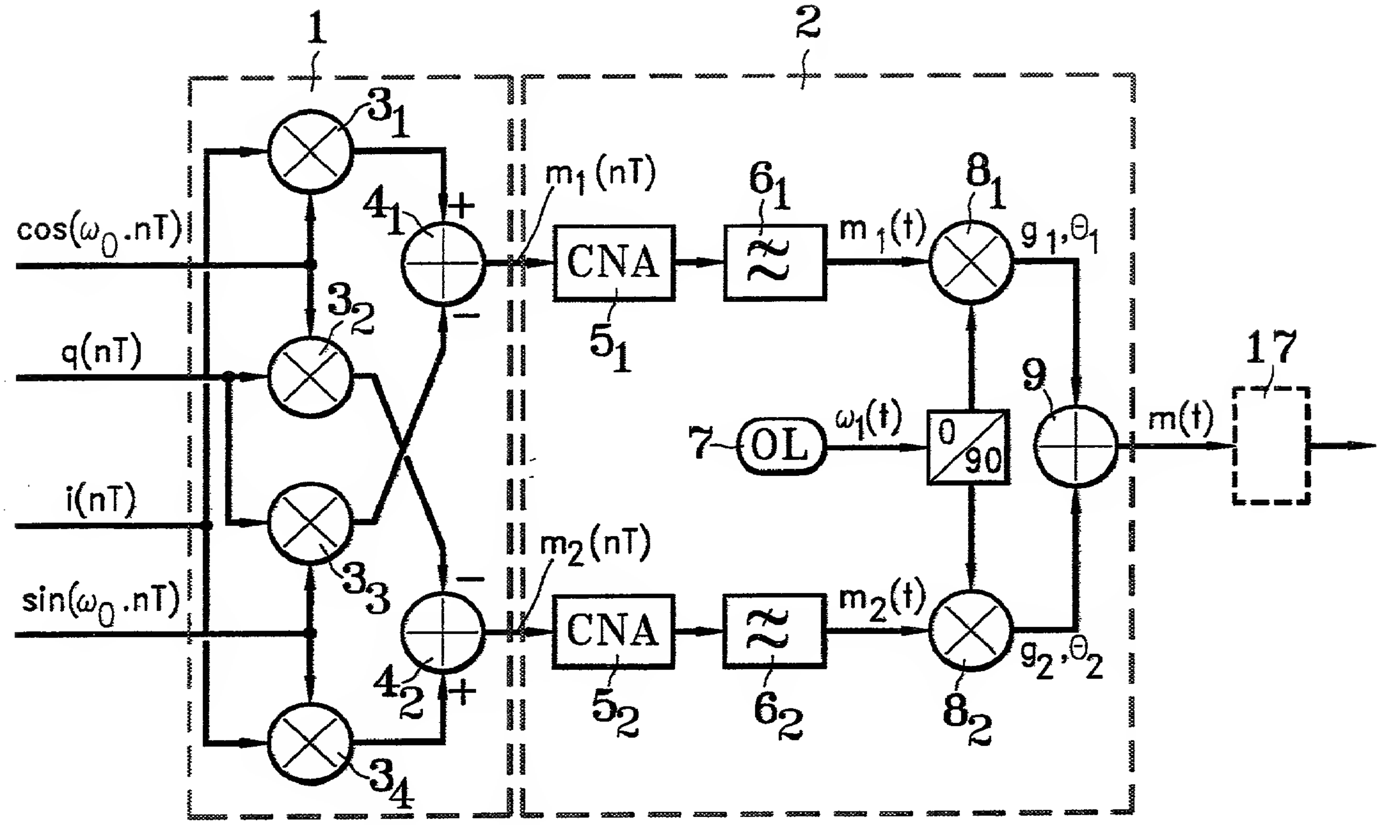
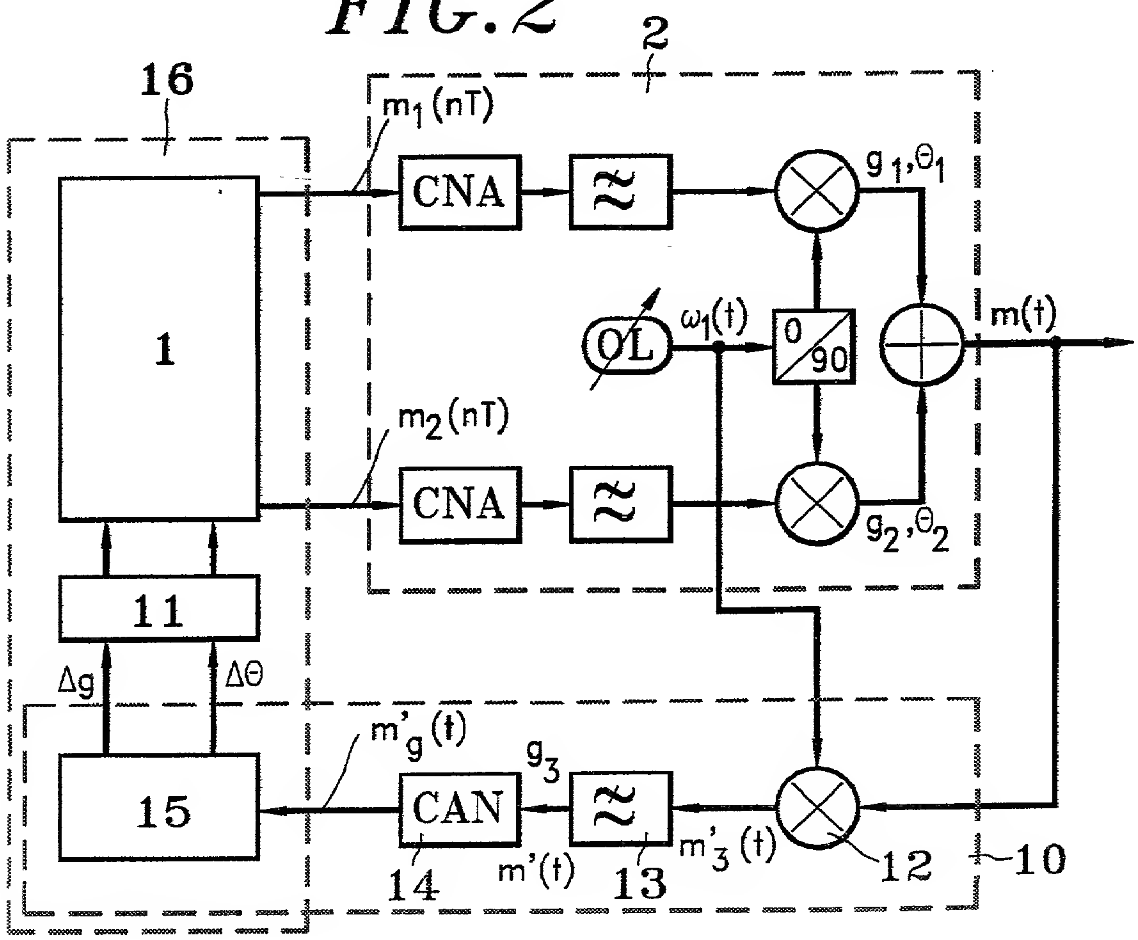

1
2
3_1
3_2
3_3
3_4
4_1
4_2
cos(ω_0.nT)
q(nT)
i(nT)
sin(ω_0.nT)
+
-
-
+
m_1(nT)
m_2(nT)
CNA
CNA
5_1
5_2
6_1
6_2
m_1(t)
m_2(t)
8_1
8_2
g_1,θ_1
g_2,θ_2
7
OL
ω_1(t)
0
90
9
m(t)
17

FIG.2


16
2
1
11
15
Δg
$\Delta\Theta$
m_1(nT)
m_2(nT)
CNA
CNA
OL
ω_1(t)
0
90
g_1,θ_1
g_2,θ_2
m(t)
m'g(t)
g_3
CAN
m'(t)
m'3(t)
14
13
12
10

Attorney Docket No. 9320.100US01

MERCHANT & GOULD P.C.

United States Patent Application

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that

I verily believe I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: RADIOFREQUENCY TRANSMITTER WITH A HIGH DEGREE OF INTEGRATION AND POSSIBLY WITH SELF-CALIBRATING IMAGE DELETION

The specification of which
a. ☒ is attached hereto
b. ☐ was filed on as application serial no. and was amended on (if applicable) (in the case of a PCT-filed application) described and claimed in international no. filed and as amended on (if any), which I have reviewed and for which I solicit a United States patent.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, § 1.56 (attached hereto).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119/365 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on the basis of which priority is claimed:

a. ☐ no such applications have been filed.
b. ☒ such applications have been filed as follows:

FOREIGN APPLICATION(S), IF ANY, CLAIMING PRIORITY UNDER 35 USC § 119			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**
France	99 03768	23 March 1999	
ALL FOREIGN APPLICATION(S), IF ANY, FILED BEFORE THE PRIORITY APPLICATION(S)			
COUNTRY	**APPLICATION NUMBER**	**DATE OF FILING (day, month, year)**	**DATE OF ISSUE (day, month, year)**

I hereby claim the benefit under Title 35, United States Code, § 120/365 of any United States and PCT international application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. APPLICATION NUMBER	**DATE OF FILING (day, month, year)**	**STATUS (patented, pending, abandoned)**

I hereby claim the benefit under Title 35, United States Code § 119(e) of any United States provisional application(s) listed below:

U.S. PROVISIONAL APPLICATION NUMBER	**DATE OF FILING** (Day, Month, Year)

I hereby appoint the following attorney(s) and/or patent agent(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected herewith:

Albrecht, John W.	Reg. No. 40,481	Lacy, Paul E.	Reg. No. 38,946
Anderson, Gregg I.	Reg. No. 28,828	Larson, James A.	Reg. No. 40,443
Ansems, Gregory M.	Reg. No. 42,264	Liepa, Mara E.	Reg. No. 40,066
Batzli, Brian H.	Reg. No. 32,960	Lindquist, Timothy A.	Reg. No. 40,701
Beard, John L.	Reg. No. 27,612	Lycke, Lawrence E.	Reg. No. 38,540
Berns, John M.	Reg. No. 43,496	McAuley, Steven A.	Reg. No. P-46,084
Black, Bruce E.	Reg. No. 41,622	McDonald, Daniel W.	Reg. No. 32,044
Branch, John W.	Reg. No. 41,633	McIntyre, Jr., William F.	Reg. No. P-44,921
Bremer, Dennis C.	Reg. No. 40,528	Mueller, Douglas P.	Reg. No. 30,300
Bruess, Steven C.	Reg. No. 34,130	Pauly, Daniel M.	Reg. No. 40,123
Byrne, Linda M.	Reg. No. 32,404	Pendergast, Paul	Reg. No. 46,068
Carlson, Alan G.	Reg. No. 25,959	Phillips, John B.	Reg. No. 37,206
Caspers, Philip P.	Reg. No. 33,227	Plunkett, Theodore	Reg. No. 37,209
Chiapetta, James R.	Reg. No. 39,634	Pytel, Melissa J.	Reg. No. 41,512
Clifford, John A.	Reg. No. 30,247	Qualey, Terry	Reg. No. 25,148
Cochran, William W.	Reg. No. 26,652	Reich, John C.	Reg. No. 37,703
Daignault, Ronald A.	Reg. No. 25,968	Reiland, Earl D.	Reg. No. 25,767
Daley, Dennis R.	Reg. No. 34,994	Schmaltz, David G.	Reg. No. 39,828
Dalglish, Leslie E.	Reg. No. 40,579	Schuman, Mark D.	Reg. No. 31,197
Daulton, Julie R.	Reg. No. 36,414	Schumann, Michael D.	Reg. No. 30,422
DeVries Smith, Katherine M.	Reg. No. 42,157	Scull, Timothy B.	Reg. No. 42,137
DiPietro, Mark J.	Reg. No. 28,707	Sebald, Gregory A.	Reg. No. 33,280
Edell, Robert T.	Reg. No. 20,187	Skoog, Mark T.	Reg. No. 40,178
Epp Ryan, Sandra	Reg. No. 39,667	Spellman, Steven J.	Reg. No. 45,124
Glance, Robert J.	Reg. No. 40,620	Stoll-DeBell, Kirstin L.	Reg. No. 43,164
Goggin, Matthew J.	Reg. No. 44,125	Storer, Shelley D.	Reg. No. 45,135
Golla, Charles E.	Reg. No. 26,896	Sumner, John P.	Reg. No. 29,114
Gorman, Alan G.	Reg. No. 38,472	Sumners, John S.	Reg. No. 24,216
Gould, John D.	Reg. No. 18,223	Swenson, Erik G.	Reg. No. 45,147
Gregson, Richard	Reg. No. 41,804	Tellekson, David K.	Reg. No. 32,314
Gresens, John J.	Reg. No. 33,112	Trembath, Jon R.	Reg. No. 38,344
Hamre, Curtis B.	Reg. No. 29,165	Underhill, Albert L.	Reg. No. 27,403
Hillson, Randall A.	Reg. No. 31,838	Vandenburgh, J. Derek	Reg. No. 32,179
Holzer, Jr., Richard J.	Reg. No. 42,668	Wahl, John R.	Reg. No. 33,044
Johnston, Scott W.	Reg. No. 39,721	Weaver, Karrie G.	Reg. No. 43,245
Kadievitch, Natalie D.	Reg. No. 34,196	Welter, Paul A.	Reg. No. 20,890
Karjeker, Shaukat	Reg. No. 34,049	Whipps, Brian	Reg. No. 43,261
Kastelic, Joseph M.	Reg. No. 37,160	Wickhem, J. Scot	Reg. No. 41,376
Kettelberger, Denise	Reg. No. 33,924	Williams, Douglas J.	Reg. No. 27,054
Keys, Jeramie J.	Reg. No. 42,724	Witt, Jonelle	Reg. No. 41,980
Knearl, Homer L.	Reg. No. 21,197	Wu, Tong	Reg. No. 43,361
Kowalchyk, Alan W.	Reg. No. 31,535	Xu, Min S.	Reg. No. 39,536
Kowalchyk, Katherine M.	Reg. No. 36,848	Zeuli, Anthony R.	Reg. No. 45,255

I hereby authorize them to act and rely on instructions from and communicate directly with the person/assignee/attorney/firm/ organization who/which first sends/sent this case to them and by whom/which I hereby declare that I have consented after full disclosure to be represented unless/until I instruct Merchant & Gould P.C. to the contrary.

Please direct all correspondence in this case to Merchant & Gould P.C. at the address indicated below:

Merchant & Gould P.C.
3100 Norwest Center
90 South Seventh Street
Minneapolis, MN 55402-4131

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2	**Full Name Of Inventor**	**Family Name** Andre	**First Given Name** Eric	**Second Given Name**
0	**Residence & Citizenship**	**City** Grenoble	**State or Foreign Country** France	**Country of Citizenship** France
1	**Post Office Address**	**Post Office Address** 18, rue Lachmann	**City** Grenoble	**State & Zip Code/Country** 38000 / France
Signature of Inventor 201:			**Date:**	

§ 1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is canceled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is canceled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§ 1.97(b)–(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

(1) prior art cited in search reports of a foreign patent office in a counterpart application, and

(2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

(1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim;

or

(2) It refutes, or is inconsistent with, a position the applicant takes in:

(i) Opposing an argument of unpatentability relied on by the Office, or

(ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden–of–proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

(1) Each inventor named in the application:

(2) Each attorney or agent who prepares or prosecutes the application; and

(3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.

(d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.